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13. ABSTRACT *(Maximum 200 words)*

We carry out theoretical and numerical studies of resolution limits for imaging and beam-forming (time reversal) with an active array when the ambient medium is noisy. We analyze in detail some new problems that emerge in the asymptotics of stochastic differential equations, which play an essential role in the formulation of imaging methods. We also analyze the phenomenon of super-resolution in time reversal, where the random medium improves the resolution beyond the diffraction limit, and contrast this with image degradation. Applications range from foliage and ground penetrating radar to secure wireless communications in noisy environments.

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Final Report on Signals, Waves and Transport under grant AFOSR/DARPA F49620-98-1-0211 for the period ending January 31, 2001

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Abstract

We carry out theoretical and numerical studies of resolution limits for imaging and beam-forming (time reversal) with an active array when the ambient medium is noisy. We have analyzed in detail some new problems that emerge in the asymptotics of stochastic differential equations, which play an essential role in the formulation of imaging methods. We also analyze the phenomenon of super-resolution in time reversal, where the random medium improves the resolution beyond the diffraction limit, and contrast this with image degradation. Applications range from foliage and ground penetrating radar to secure wireless communications in noisy environments.

Objectives

Our objective has been to develop and analyze array imaging methods that work well in random media. Most imaging methods give good resolution in uniform media, for example synthetic aperture array methods, but do not perform well when there are inhomogeneities in the ambient medium. We want to use our understanding of super-resolution in time reversal, where the random medium improves the resolution beyond the diffraction limit, to develop robust array imaging methods. We also want to use our experience and understanding of stochastic equations to analyze the resolution limits of such methods.

Status of effort

We have at this time a rather complete analysis of super-resolution in time reversal based on the asymptotics of stochastic equations. We have also done extensive numerical experiments that explain the statistical stability of super-resolution in the time domain and the overall robustness of the asymptotic analysis. We have also done numerical calculations of time reversal in a solid-liquid interface.

In imaging, we have completed a detailed numerical study of array imaging using subspace projection methods in the time domain along with arrival time estimation. This new imaging methodology performs very well in random media. We are now beginning the mathematical analysis of this approach. We are also setting up a much more extensive computational environment in which we can carry out realistic imaging simulations.

Accomplishments

Our main accomplishments are:

- Identification of the mechanisms that give statistical stability of super-resolution in the time domain, as observed in real and numerical experiments.
- A complete theoretical study of the statistical problems that arise in super-resolution using the asymptotics of stochastic equations.
- The development of robust array imaging in the time domain using subspace projection methods as well as arrival time analysis that perform well in random media.

Personnel Supported

During this period we had the following visitors, some of whom are staying on.
Peter Blomgren from UCLA working on time reversal imaging.
Miguel Moscoso from Spain.
Arnold Kim from the University of Washington.
Liliana Borcea on sabbatical leave from Rice University.
Chrysoula Tsogka from INRIA France.
Mark Alber on sabbatical leave from Notre Dame.

1 Interactions/Transitions

Several invited lectures in the US and Europe including lectures on time reversal and imaging at the annual DARPA meetings.

Honors

Fellow of the American Academy of Arts and Sciences and member of the National Academy of Sciences.

Publications

All papers cited here that have not yet appeared in print can be accessed from http://georgep.stanford.edu (in compressed PostScript or pdf format)